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# EXACT ENGLISH LANGUAGE TRANSLATION OF THE APPLICATION AS ORIGINALLY FILED WITH ABSTRACT

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# Hot Flow Forming and Bending Method, and Device for Carrying Out said Method

The present invention has as its object a method for hot flow forming and bending, and an apparatus for carrying out this method according to the precharacterizing portion of claims 1 and 11.

From prior applications by the same applicant it is known to use so-called four-roller bending machines to bend even sensitive and thin-walled, closed, half-open and open structural sections.

The bending takes place in the form of two-dimensional or also three-dimensional forming processes.

When forming structural sections, e.g., sections made of magnesium alloys, or also in the case of high-strength steels, it has been shown that a process of bending by means of cold-forming alone is not sufficient. Due to the high tensile strength of the material to be formed, and due to an associated brittleness, the ductility is not sufficient to form the structural section in a satisfactory manner. At certain strains the structural section breaks, cracks, or is damaged in some other form, so that up to now it has not been possible to bend sensitive structural sections of this type.

In the case of thin-walled structural sections, in particular, it has been shown that these sections tend to bulge, and a forming process has not been feasible up to now.

The invention is therefore based on the object to propose a novel method for a bend forming of thin-walled and sensitive, open, half-open, and closed structural sections, which is reliable in its operation.

To meet the above object, the invention is characterized by a method according to the technical teaching of claim 1.

It is essential that at least those rollers that are disposed in the roll-bending zone are heated.

In a preferred embodiment of the invention, provision is made for the rollers that are disposed there and arranged across from each other, and that come to rest against the opposed walls of the structural section, to be heated accordingly.

Even though, in the following description, the term "forming roller" is used for at least one of these two rollers, this should not be taken literally, as the function of these rollers no longer exclusively consists of a roll-out function, but they additionally serve as forming guide for the structural section in the roll-bending zone. The actual bending of the structural section takes place in the space between the bending roller located at the rear in the feeding direction and at least one support roller arranged spaced apart from it toward the front in the feeding direction.

The invention is not limited, however, to the heated arrangement of forming rollers in the region of the roll-bending zone. It goes without saying that additional rollers may be heated as well, especially the support roller that is disposed proximally of the roll-bending zone in the feeding direction, and the opposed counter-roller that allows the structural section being bent to be supported relative to the bending roller located in front in the feeding direction.

In lieu of the described four-roller bending machine, other roller-bending machines can thus be implemented in a heated form as well. It is therefore only by way of example that the invention will be explained based on a four-roller bending machine. The technical teaching according to the invention, however, applies to all known bending methods.

To implement the heating, there also exist different embodiments, all of which shall be considered encompassed by the object of the present invention.

In a first preferred embodiment of the invention, provision is made for the forming rollers that are disposed across from each other in the roll-bending zone (namely the upper forming roller and the opposed central roller) to be designed electrically conductive (high-current carrying). For this purpose each forming roller carries an exterior current-carrying jacket that is radially inwardly electrically insulated from an interior carrier by an insulating ring, said carrier being connected to the shaft in a manner known *per se* so as to be integral in rotation therewith.

The roller across from it is implemented in the same way. If a relatively high current of e.g., 1000 to 2000 ampere is now applied to one roller, a number of current conducting paths with different flow directions are created that extend at least partly through the structural section being bent. Due to a corresponding resistance heating, the structural section is highly effectively heated in a targeted manner only in the roll-bending zone. These current conducting paths – as explained above – partly extend through the structural section to be bent. However, the current conducting paths also partly extend inward toward a mandrel shank that is held in the region of the roll-bending zone, over whose mandrel rod a portion of the current flows is also branched off to the outside. This causes the resistance heating to take effect in the interior of the structural section as well.

An additional current flow takes place through the opposed rollers directly under electrical insertion of the conductive structural section, so that only the roll-bending zone is heated to very high temperatures in a concentrated manner and with a high degree of efficiency.

During the forming of thin-walled magnesium sections or magnesium-alloy sections, temperatures are created in the roll-bending zone, in this case, between approximately 150 and 200°C.

During the forming of high-strength sheet steel sections, on the other hand, temperatures in the

range between 700 and 900°C are preferred.

It is an important aspect in this embodiment that a relatively high degree of heating takes place in a concentrated form only in the roll-bending zone. This heating is generated preferably by means of the above-mentioned current-flow resistance heating system.

The invention is not limited to this, however. The invention may also provide for the opposed forming rollers to be equipped with cartridge-type heaters, which are known *per se,* that pre-heat the forming rollers.

It is also possible to insert heating spirals into the opposed forming rollers, again to heat these by means of an appropriate current flow.

In addition to the discussed resistance current flow heating system and the heating with individual heating elements, provision is made in a further development of the invention for the forming rollers to be heated by other heating means, e.g., by means of liquid heating means that are channeled into the interior of the forming rollers; by hot-air heating means acting directly on the rollers; by means of infrared heating; or by means of inductive heating of the forming rollers.

These forming rollers may also be heated with the aid of laser energy. All of the mentioned heating methods may also be combined among each other.

The invention is also not limited to heating the forming roller and the central roller that is disposed across from it relative to the roll-bending zone.

In a further development of the invention provision is also made for so-called vertical forming rollers, which are disposed perpendicular to the above-mentioned two rollers, to be heated in

addition. All of the heating processes as they have been described above are used in this case. Said vertical forming rollers come to rest against the side wall of the structural section to be bent, where they channel heat in a concentrated manner into the structural section to be bent, into its side wall.

Especially when the above-mentioned current-flow heating system is used, current-flow paths are produced that also extend over the vertical forming rollers.

The invention is not limited to only the heating of forming rollers in the region of the roll-bending zone, but provision is made in a further development for those rollers to be heated that are disposed toward the front in the feeding direction. These are the support roller and the counter roller disposed across from the support roller, which, again, both come to rest against the opposed walls of the structural section.

These two rollers, too, can be heated using any of the above-described heating mechanisms. The heating in this region then corresponds to a pre-heating of the structural section, which is then ultimately raised in its temperature and heated in a concentrated manner in the roll-bending zone. This significantly improves the forming even of sensitive structural sections.

As a result of the controlled placement of current conducting paths that result from the opposed forming rollers coming to rest against the structural section in the roll-bending zone in an electrically conductive manner, precisely defined current conducting paths are obtained, so that it is possible as a result of applying the current, to regulate the temperature in the roll-bending zone with an accuracy of +/- 1 °C.

For regulating purposes, corresponding temperature sensors that regulate the flow of current through the setup are disposed on the opposed forming rollers.

In a further development of the invention, provision is also made for an additional pre-heating to take place at the structural section loading side, namely in the region of the machine frame. This preheating may consist of a heating channel in whose interior a plurality of heating stations are arranged in tandem.

These heating stations may provide a specified heating of the structural section in any desired manner.

It is preferred in this context, however, that each heating station is implemented in the form of a radiant panel (IR heater). However, besides the radiant panel, other heating mechanisms may be used as well, such as induction heaters and preferably other non-contact heating methods.

The present technical teaching offers the advantage that even very sensitive magnesium and magnesium alloy or aluminum-magnesium alloys can be reliably formed for the first time, without resulting in breakage or bulging of the structural section.

To support the structural section from the inside, a mandrel shank is moved along in the interior of the structural section, said mandrel being fixed to a mandrel rod.

In this context it is preferred that a link chain is disposed at the front end, which runs through the interior of the structural section in a supporting manner and extends out of the bending zone into the region of the bending roller in order to thus form a matching counter support for the bending roller.

In this manner a support for the structural section is achieved relative to the bending roller, so that the bending roller cannot deform the structural section afterward.

Provision is made in a further development of the invention in this case for the mandrel shank to be

heated. As already stated earlier, the heating preferably takes place by means of the described current flow heater.

For the purpose of heating the mandrel shank, however, all of the other above-mentioned heating mechanisms may be used as well; either individually and/or in combination among each other, especially a radiant panel, a fluid-based heater, a laser heater, and others more.

The object of the present invention is derived not only from the subject matter of the individual claims, but also from the combination of the individual claims among each other.

All disclosed information and features contained in the documentation, including in the abstract, especially the three-dimensional design depicted in the drawing, are claimed as essential to the invention to the extent that they are novel with respect to the prior art, either individually or combined.

In the following text the invention will be explained in more detail based on drawings that show only a single embodiment. Additional characteristics that are essential to the invention and advantages of the invention will also become apparent from the drawings and description of the same, in which

Figure 1: is a schematic perspective view of a hot flow forming and bending machine according to the invention

Figure 2: is an enlarged partial view of the bending head, shown in a section

Figure 3: is the depiction of the hot flow forming and bending machine according to Figure 1

with additional details

Figure 4: is a section according to line IV-IV in Figure 3

Figure 5: is a section according to line V-V in Figure 3

Depicted in Figure 1 is a machine frame, having fixed on it a number of guide stations 3, 4, 5 operating in tandem. Disposed at the rear of the machine frame is a mandrel holder station 2 for supporting 2 mandrel rods 6, 7.

The guide stations 3, 4, 5 serve both for guiding the mandrel rods 6, 7, as well as for guiding a structural section 21 to be formed, which is not shown in detail.

In a manner not shown in detail, this structural section 21 is clamped into a clamping head 8, which is connected to a sliding table 9.

The sliding table 9 is moved driven by drives 10 in the longitudinal direction of the machine frame 1, in order to thus insert the structural section 21 to be bent into the bending head 70.

Additional details will become apparent from Figures 2 and 3.

Figure 3 shows that it is essential in one embodiment that the structural section 21 to be formed has an associated heating channel 30.

This heating channel consists of a number of heating stations 31, 32, 33 operating in tandem; each heating station having a plurality of radiant panels 34, 35.

Additionally disposed in the heating channel 30 are guide rollers 37, which are supported oscillating and which are positioned by means of spring elements 38 against the structural section 21 to be

formed.

The section through the half-channel [1] 30 is shown in Figure 4. In this drawing the individual above-mentioned parts are shown in a section.

In lieu of 2 mandrel rods 6, 7 – as shown in Figure 1 – only one single mandrel rod 6 is used in this case.

Referring to Figures 2 and 3, the novel bending head 70 according to the invention will now be explained in more detail.

It essentially comprises a central roller 11, which is rotatably supported on a rotational axis 12 and which is driven, for example, so as to rotate in the direction of the arrow 29.

The central roller 11 has disposed across from it – across from the structural section being bent – a forming roller 14 in such a way that a roll-bending zone 40 for the structural section 21, 21' to be formed is defined by these two forming rollers 11, 14.

The forming roller 14 may thus be driven and, in addition, the sliding table 9 operates in the direction of the longitudinal axis of the structural section 21 in order to push the same through the roll-bending zone 40.

Disposed in the interior of the hollow structural section, in the region of the roll-bending zone 40, is a mandrel shank 25, in this case, which is preferably composed of multiple elements.

The rearward end of the mandrel shank 25 is formed by a first support element 26, which is arranged

[1] Translator's note: This appears to be a typographical error in the German-language document. The intended German word may have been "Heizkanal" (heating channel) instead of "Halbkanal " (half-channel).

in the gap between a support roller 17 and a counter roller 18 disposed opposite the [2].

In the region of the roll-bending zone 40 the mandrel shank 25 forms a second support element 27, which prevents a denting or caving-in of the structural section in the region of the roll-bending zone 40.

In the region toward the front, the mandrel shaft 25 is connected to a link chain 28, which is composed of individual links that are connected to each other in an articulated fashion, which come to rest against the interior wall of the hollow structural section, said link chain 28 extending into the region of the bending roller 13.

The bending roller 13 is designed pivoting and can be moved as desired toward the structural section 21' to be bent, in order to thus achieve a specified bend.

The bending of the structural section to be formed thus preferably takes place via the bending roller 13 acting upon the structural section 21 to be formed, causing a corresponding counter pressure by the support roller 17 that is disposed at a distance behind it.

The forming (a hot flow forming and bending process), however, takes place in the region of the roll-bending zone 40.

Figure 5 shows that in the region of the roll-bending zone 40 additional forming rollers may be disposed, which come to rest against the upper and lower side wall of the structural section. The vertical forming rollers 15, 16 are shown in Figure 5.

The purpose of these vertical forming rollers is to additionally guide the structural section in the

[2] Translator's note: This translation is based on an incomplete sentence in the German-language document.

region of the side wall and prevent a lateral yielding in this region.

In other respects, it is not shown in detail that additional vertical forming rollers 19, 20 may also be disposed in the region of the support and counter roller 17, 18, again in a perpendicular plane relative to them, as it is indicated in Figure 2.

In other respects, the entire structural section 21 rests on a supporting table 22 to prevent the structural section from sagging.

In other respects, the bending head has a bottom 23 and an upper cover 24.

An important aspect now is the electric current-flow heater in the region of the roll-bending zone 40, as it is shown in more detail based on Figure 2.

First, it is apparent that the upper forming roller 14 is rotatably supported on a sliding table 65, which is designed movable toward and away from the structural section being bent. To this sliding table 25, one terminal of a current-flow source will now be applied, while the other terminal of the current-flow source is connected electrically conducting to an opposed central roller 11.

This results in the creation of the current conducting paths 55-64, which are marked in the drawing in detail with the current conducting paths A1 through A10.

For example, the current conducting path A1 extends from the central roller 11 over the electrically conductive jacket 41 onto the surface of the structural section 21, where it is rerouted in the form of the current conducting path 62 (A8) and flows off over the structural section.

The current conducting path A3 transitions into the current conducting path A4. The current

conducting path A5 transitions into the current conducting path A6. The current conducting path A7 transitions into the current conducting path A8. The current conducting path A9 transitions into the current conducting path A10.

All current conducting paths are linked as a network and connected to each other in an electrically conducting manner.

Due to the application of a relatively large current that flows over the electrically conductive jacket 41 of the forming roller 14 onto the electrically conductive structural section 21, and from this structural section onto the electrically conductive jacket 41 of the central roller 11, concentrated high-energy heating zones are created in the region of the roll-bending zone 40, so that the sensitive structural section is heated in a concentrated manner only in the region of this forming zone.

Also depicted is that the same heating mechanisms with the current conducting paths may also be disposed in the region of the vertical forming rollers 15, 16 that are disposed perpendicular to the former.

Also depicted is that the mandrel shank 25 is designed electrically conductive as well, with the support elements 26, 27 also being electrically conductive, and the current then ultimately being branched off toward the rear over the mandrel rod 6.

In other respects, Figure 2 also shows that the support roller 17 and counter roller 18 are also electrically heated in the same manner, with a corresponding current flow being applied via the sliding table 66; and the opposite terminal, for example, being connected electrically conductive to the jacket of the counter roller 18.

This results in the current conducting paths 45-54 with the designations B1 through B10 marked in the drawing.

In this case, too, the result is a multiple branching of the current conducting paths; this current-flow heating in the region of the support roller 17 and counter roller 18 being considered a preheating for the actual heating in the roller bending station 40.

In this case, too, provision may be made for vertical forming rollers 19, 20, which may be heated in the same manner, to be arranged perpendicular to the former.

In other respects, the bending roller 13 is also supported on a sliding table 67, with the bending roller 13 not being heated, however,

As already mentioned at the beginning, each roller 11, 14, 17, 18, 15, 16, 19, 20 that is heated by means of a current-flow heater consists of an electrically conductive jacket 41, which is insulated from an electrically conductive carrier 42 by means of an electrically insulating insulating ring 43. The respective carrier 42 then is connected to the shaft 44 in each case so as to be integral in rotation therewith.

Referring to Figure 3, it should also be noted that the discharge side of the heating channel 30 is provided with an end plate 39 in order to prevent excessive dissipation of the heat being generated there from the heating channel 30.

The entire heating equipment has assigned to it an appropriately sized transformer that makes the corresponding electrical power available.

The fundamental difference of the inventive hot flow forming and bending method compared to the

cold flow forming and bending lies in that, in the case of the cold flow forming and bending, the bending rollers is required [3] a certain penetration depth into the material of the structural section to be formed in order to attain a grain flow. This grain flow is attained by means of a roll-out effect, which, in turn, is achieved by a certain penetration depth of the profile cross section into the structural section to be formed. Herein lies a significant difference to the novel inventive hot flow forming and bending, since – as presented above – the actual forming rollers, namely the central roller 11 and forming roller 14, no longer perform an actual rolling-out of the structural section, but merely assume a support function and conduction of a current.

As a result of the resistance-type heating in the roll-bending zone 40, a temperature rise is generated in the structure of the structural section to be formed, in order to thus render the structure bendable. A corresponding magnesium section would not be formable at room temperatures. In this case, the above-mentioned twisted [4] heating is made possible in the roll-bending zone, in order to render the grain of the magnesium alloy flowable and permit a forming in the region between the bending roller 13 and the support roller 17 that is disposed at a distance from it.

With respect to a high-strength steel material, this means that this high-strength steel material must be heated in the roll-bending zone in a temperature range between 700 and 1000°C, in order to likewise permit a grain flow in the roll-bending zone, and to thus be able, for the first time, to allow for a forming of this structural section.

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[3] Translator's note: This translation is based on an incomplete sentence in the German-language document.

[4] Translator's note: The translation "torsional" is based on the German word "verdreht" (= twisted / distorted / warped). The intended meaning is not clear to this translator.

## Drawing Legend

1 machine frame
2 mandrel holder station
3 guide station
4 guide station
5 guide station
6 mandrel rod
7 mandrel rod
8 clamping head
9 sliding table
10 drive
11 central roller
12 rotational axis
13 bending roller 13' 13"
14 forming roller
15 vertical forming roller
16 vertical forming roller
17 support roller
18 counter roller
19 vertical forming roller
20 vertical forming roller
21 structural section 21'
22 support table
23 bottom (bending head)
24 cover
25 mandrel shank
26 support element (rear)
27 support element (front)
28 link chain
29 direction of arrow
30 heating channel
31 heating station
32 heating station
33 heating station
34 radiant panel (top)
35 radiant panel (side)
36 guide means (sliding table 9)
37 guide roller
38 spring element
39 end plate
40 roll-bending zone
41 jacket
42 carrier
43 insulation
44 shaft
45 current conducting path B1
46 current conducting path B2
47 current conducting path B3
48 current conducting path B4
49 current conducting path B5
50 current conducting path B6
51 current conducting path B7
52 current conducting path B8
53 current conducting path B9
54 current conducting path B10
55 current conducting path A1
56 current conducting path A2
57 current conducting path A3
58 current conducting path A4
59 current conducting path A5
60 current conducting path A6
61 current conducting path A7
62 current conducting path A8
63 current conducting path A9
64 current conducting path A10
65 sliding table
66 sliding table
67 sliding table
68
69
70 bending head